Research, reviews & patents

Indium implant in n-MOSFET devices

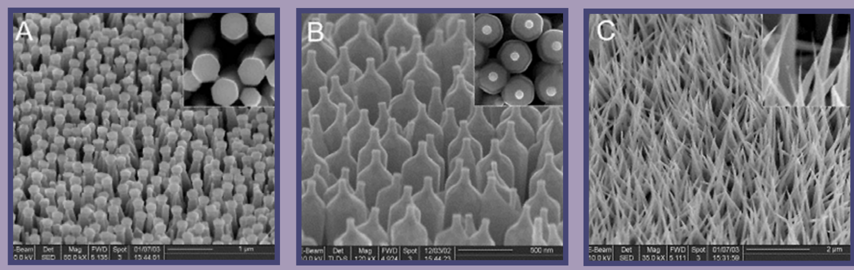
A Chartered Semiconductor Manufacturing & National University of Singapore-Nanyang Technological University joint research programme is working on short channel devices, scaled down to 0.1µm regime, and the need for a steep retrograded channel profile (SRCP) is essential.

This results in the use of indium to replace boron as a channel dopant. Using SIMS analysis, indium is shown to give an SRCP as-implanted, because of its large atomic weight of 115 and high segregation into the oxide. However, in the integration of the entire n-MOSFET, additional thermal cycles from subsequent process steps may result in severe diffusion of both the indium channel and boron pocket implants, hence degrading the SRCP.

Consequently, integration of the indium implant is crucial in reaping the advantages of SRCP. In the first part of the project, the effectiveness of NLDD RTA in maintaining the SRCP is shown. In addition, the effect of eliminating boron pocket implant will be studied. The 2-D effect in the channel region is studied using TSUPREM4 and MEDICI simulation, and a correlation with the VT roll-off profile can be established. This allows a detailed study of the Short Channel Effects (SCE) and Reverse Short Channel Effects (RSCE). http://www.ntu.edu.sg/eee/eee6/CSMproject/Proj1O_3.htm

ZnO nanorod arrays

Peking University researchers at the School of Physics have synthesised ZnO nanorod arrays with peculiar morphologies on (111) -oriented Si substrates and glass via vapour phase growth. The morphology of the individual nanorod can be flat-headed bottle-like, and needle-like, which depends on the deposition positions relative to the source materials in the presence of a controlling element Se. In addition, the arrays of all the three morphologies exhibit good alignment and high coverage. This fabrication technique can also be used to direct the controllable growth of other nanomaterials with similar morphologies, and the as-grown ZnO nanorod arrays may have potential applications in nanolasers, field emitters and other nanodevices as well. Authors: Xiaochen Sun, Hongzhou Zhang, Jun Xu, Qing Zhao, Rongming Wang and Dapeng Yu. *Solid State Communications* 129 (12) 803-807 March 2004



The morphology of the individual nanorod can be flat-headed bottle-like (b), and needle-like (c), which depends on the deposition positions relative to the source materials in the presence of a controlling element Se

1.55m InGaAsP/InP tapered stripe SLED

Researchers from the Korea Maritime University, Silla University and Saracom Co Ltd have been working on superluminescent emitting diodes (SLEDs). These have been broadly used as optimum light sources for application in optical measurement systems, such as fiber optic gyroscopes, optical time domain reflectometers, WDM systems and short and medium distance optical communication systems.

Because of the gain of SLED, much more power can be launched into a fiber than from a same size LED at the same current densities. Since SLED is less coherent and less sensitive in terms of reflection than a laser diode (LD), these properties lead to less modal, feedback, and partition noise effects. Consequently, SLED has intermediate properties between LEDs and LDs, so that some problems of the above-mentioned devices may be avoided.

To maximise the intermediate properties of SLED, a laterally tilted multiquantum well-planar buried heterostructure-separate confinement heterostructure (MQW-PBH-SCH)-SLED, with a window region and tapered active layer, was proposed.

The advantage of this method is that it obviates the need for AR coating on facets for decrease of reflectivity, because of the efficient structure. It is also easy to fabricate using a similar process of LD fabrication.

In order to suppress lasing oscillation, laterally tilted MQW-PBH-SCH SLED, with a window region and tapered active layer, was advocated. The devices were fabricated using MOCVD and LPE.

The team calculated the effective reflectivity of the window structure as a function of the window length and the fundamental TE mode reflectivity with tilted angle, active layer thickness and width. The output power and the spectral width of SLD-L15 were 11mW and 42nm respectively, at 200 mA under pulse operation and 25°C.

Coupled power of 24W and coupling efficiency of 16% into a inclined single mode fiber at 100 mA under DC operation and 25°C was achieved. The pigtailed output power of the team's SLED in CW operation is lower than that of the commercial one.

However, when the fabricated SLED was applied to the light source of a fiber optic gyroscope (FOG), a kind of optical fiber sensor, there was no problem and it operated well, even the random walk coefficient of the FOG output was 0.0025 deg/h1/2, a little bigger than that of commercial SLED. Moreover, there was room to improve the team's SLED's pigtailed output power, by adoption of the commercial-grade packaging and pigtailing with a lensed fiber.

Authors: Jeong-Ho Kim, Se-kyung An, Seok-Jeong Lee, Jung-chul Bae, Young-Kyu Choi & Tchang-Hee Hong *Optics & Laser Technology* 36 (3) 255-258 April 2004

Surface SiC implantation into silicon

In South Africa, development and growth of silicon carbide as a wide band-gap semiconductor, with superior physical properties, is currently receiving much interest. The driving force behind these efforts has been largely aerospace applications, involving high-temperature, high-radiation environments.

For some applications, such as membranes in sensors and non-volatile memory cells, only a thin film of SiC is required. High-quality, large-area SiC films can also be used as a seed for the chemical vapour deposition (CVD) growth of large-diameter SiC crystals. In addition, one can envisage electro-optical applications where well-established silicon electronic technology is used in a predominantly Si device, which has been locally upgraded in small regions to a wide band-gap material by carbon-ion implantation into the silicon substrate.

Recent work has shown that buried SiC layers with fairly sharp interfaces can be formed by medium-energy (200 keV) high-dose (10^{18}cm^{-2}) carbon implantation into Si. The authors investigate the possibility of producing a surface SiC layer on Si by low-energy (30keV) carbon implantation at a dose ranging from 101^{7} to 10^{18}cm^{-2}. Such a structure has the obvious advantage that no preliminary etching step is required to expose the SiC layer in CVD and other applications.

Optical techniques such as infra-red reflectance, Raman spectroscopy and ellipsometry were used to characterise the synthesised SiC layers. Investigations on the compositional depth profile by Auger electron spectroscopy are also provided. Ion-implanted carbon in single crystal silicon, can, upon annealing at a sufficiently high temperature (1200°C), be made to undergo chemical segregation to achieve a distinct surface layer of crystalline SiC.

Auger spectroscopy depth profiling shows a carbon-rich implanted layer for the as-implanted samples. The peak concentration is less than that predicted because of diffusion and surface segregation of the carbon. Post-implantation annealing at 1200°C caused increased carbon diffusion and the formation of stoichiometric SiC in the region around the carbon peak. Auger peak analysis confirms the formation of SiC in the layers.

Imperfect crystallinity is indicated by the too large value of the damping constant in the IR reflectance measurements. This is presumably due to the fact that the annealing temperature is limited by the melting point of the silicon substrate to below 1400°C. Ellipsometry clearly shows a consistent trend towards a higher SiC content as the implantation dose and the annealing temperature are increased. At annealing temperatures close to the melting point of the Si substrate, almost complete conversion to SiC can be obtained. There may, however, still be a thin amorphous layer below the crystalline surface layer. A longer annealing time may be required to crystallise this.

Both the IR work and the ellipsometry indicates that the implantation layer is slightly carbon-rich and the implantation dose be lowered by 10-20%. The final stoichiometry is determined by the dynamically changing stopping power during implantation and by diffusion effects during annealing. Consequently, it is best determined by experiment.

Authors: D. J. Brink, J. Camassel and J. B. Malherbe *Thin Solid Films* 449 (1-2) 73-79 2 February 2004

China semiconductor industry directory

A bilingual *English Chinese Directory of China Semiconductor Industry Asssociation* has been published. It lists some 350 semiconductor enterprises in China involved in IC and discrete device manufacturing, R&D, package & test, as well as semiconductor equipment & materials, giving manufacturers name and address, director names, tel/fax, email as well as business activity and product lines.
Price for the directory is $165.50 from Business Data International Inc, Box 28547, verdun Ave, Montreal, QCH4G3L7.
Email: info@businessdataint.com

Silicon carbide devices galore

Anyone looking to discover what loops a SiC device can jump through should cast an eye at Purdue's SiC Data Bank. You would expect Power MOSFETs, Lateral Power MOSFETs and Schottky Barrier Diodes. But Purdue also has Microwave devices, with two types under development: a vertical static induction transistor (SIT) and a lateral MESFET, with sub-micron gate. Then there's IMPATT Diode microwave oscillators. These are two-terminal semiconductor devices that generate RF power by introducing a 180° phase shift between current and voltage waveforms at microwave frequencies. "We have fabricated the first IMPATT diodes in 4H-SiC. These devices exhibit microwave oscillations at around 8 GHz when operated in an X-band waveguide cavity under pulsed bias."

CMOS Integrated Circuits: The first 6H-SiC CMOS digital IC was completed September '96; a 2G was in March '97. These were the first SiC CMOS circuits fabricated with an implanted P-well process, and first to operate on a single 5 V power supply.

Nonvolatile Memories: The thermal generation rate in semiconductors is proportional to the intrinsic carrier concentration ni, and ni decreases exponentially with band gap energy. Wide band gap semiconductors have dramatically lower thermal generation, with the thermal generation rate of 6H-SiC being about 16 orders-of-magnitude lower than Si. This makes it possible to construct one-transistor memory cells in SiC which retain information for many years without power.

Charge Coupled Devices: CCDs are unique MOS devices in which charge packets are shifted laterally along the semiconductor surface by appropriate clocking applied to surface electrodes. CCDs are widely used as imagers in video cameras and digital still cameras. Purdue developed the first CCDs in SiC, where the wider bandgap makes it possible to image scenery in the UV portion of the spectrum without being ovewhelmed by visible light.

NMOS Integrated Circuits: The low thermal generation rate in SiC makes it possible to operate integrated circuits at much higher temperatures than silicon. The group developed the first digital integrated circuits in SiC in late 1993. These early circuits were implemented in enhancement mode NMOS.

Web: http:// www ecn. purdue .edu/ WBG/ Data_Bank/